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Delineation of Water Quality Aspects Through Water Quality Index Using GIS and Statistical Approach in Faisalabad

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Drinking water is essential for life and survival, deterioration of its quality may affect human being at global level. Therefore, monitoring of water quality is essential component for life cycle. For this purpose, a study was carried out in Faisalabad tehsil to monitor the water quality aspects using Water Quality Index (WQI). Six parameters were selected like EC, Turbidity, TDS, Nitrates, Arsenic and Fluorides, their individual effect beyond threshold levels and combined effect on water rating scale was determined using GIS and statistical approach. Thirteen sampling locations were selected to determine the Water Quality Index. Statistical approach provided the maximum, minimum, mean and standard deviation of parameters among sampling locations. These parameters were spatially distributed using arc map to provide conversant approach at tehsil level. Relative weights of influencing parameters (Wi), Water quality rating scale (Qi) which is ratio of concentration of parameters in the water sample to standard value of parameters. Combined effect of Wi and Qi provided WQI as rating scale value which was between 22 to 375. After analysis, it determined the water quality as excellent (7.5%), good (23.07%), poor 30.76%), very poor (15.38%) and unfit for drinking purpose (23.07%). It prevailed that water should be filtered or purify before use to avoid hazardous effect on human health.

Keywords: Deterioration, water Quality Index (WQI), GIS, Water rating, relative weight, parameters.

INTRODUCTION

The vicinity of groundwater withdrawal has deep impact on economy of country due to major contribution to agricultural and industrial sector, but the quality of groundwater has been deteriorating at alarming rate world widely (Organization & UNICEF., 2013). Anthropogenic activities and irregular development of industrial and domestic usage has put pressure on groundwater abstraction which has created lowering of water level and quality worldwide especially in Pakistan Industrial (Abbas *et al.*, 2017; Aleem *et al.*, 2018). Industrial sector is the second major contributor on economy of country by 13.5% in GDP and it shares a major impact on water withdrawal in Pakistan (Rehman & Deyuan, 2018). The declination of groundwater level has affected the water supplies to agriculture land adversely because farmers were unable to use surface and groundwater due to low availability and shallow aquifer, In district Hafizabad it was observed a rapid decline of groundwater which put pressure on water energy nexus (Awais *et al.*, 2020).

In Faisalabad, at Chokera water quality index (WQI) was used to determine the effect of fourteen parameters like TDS, TSS, EC, pH, DO, Carbonates, bicarbonates, Chlorides, Arsenic, Lead, Cadmium, Copper, Chromium and Zinc and it was determined that water quality of Chokera area was varied from poor to very poor. It was recommended to use water after purification and treatment to avoid illness and serious deceases

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(Afif *et al.,* 2019). In order to improve the water quality, aquatic plants could be used at large scale which optimize water quality by absorbing hazardous parameters. In Turkey, sinking rhizosphere plants were used to reduce pollutants from water, after treatment the water quality was found in acceptable limits (Ali *et al.,* 2022).

Water quality index is a well-known, simple, and relative measurement method used for determination of water quality, it is defined as relative rating of water quality influencing factors on the basis of their impact on quality (Brown *et a*l., 1970). WQI was used by (Pamei *et al.,* 2022) in Dimapur district to determine the influence of harmful trace elements on water contamination. He used Temperature, PH, EC, TDS, DO, Fe, SO_4, TH, NO_3 and PO_4 parameters to quantify the quality of water by statistical co relation and WQI, he evaluated the water quality was from poor to very poor index due to variation water parameters and water is not fit to use without filtration. The aim of this study is to investigate the groundwater quality of bore wells and motor pumps which is being used intensively for the drinking and irrigation purposes as well. Water quality index is the base parameter used for the investigation of groundwater quality. Arc GIS tool was used to draw the spatial distribution and to check the geo-influence of groundwater quality from one point to other point.

MATERIALS AND METHODS

The research was carried out in Faisalabad an industrial city, Elevation from sea level is 184 m, it is situated between Ravi and Chenab rivers (Rechna Doab) and lies at upper side of Punjab province. The district Faisalabad has six tehsils i.e., Faisalabad, Samundri, Chak Jhumra, Faisalabad Saddar, Tandlianwala and Jaranwala. Total geographical area of district is 5856 km^2 and designed study was taken under Faisalabad tehsil area, approximate area of Faisalabad tehsil is more than 200 km^2 (Sajjad *et al.,* 2022). Climate of study area is categorized by large seasonal fluctuations in temperature. Overall, four season are affecting climate of area which are Spring, Summer, Autumn and winter, summer is quite hot, and it lasts through April to September with variation in temperature 21-51^{o}C. and in Winter season from December to February daytime temperature is between 15-27^{o}C. Rainfall is categorized as semi-arid region with mean rainfall about 450mm. highest rainfall was observed during monsoon period through July & August accounting 60% of average annual rainfall (Khan et al., 2022). Geographically study area is lied between well irrigated with soil profile loam to sandy loam and unconfined aquifer (Shakoor *et al.,* 2020; Zouhri & Armand, 2021).

Description of sampling site: Thirteen sampling points were selected from water pumping and local borewells their description is mentioned in table 1. These samples were collected in water bottles 500ml which were tested in laboratory

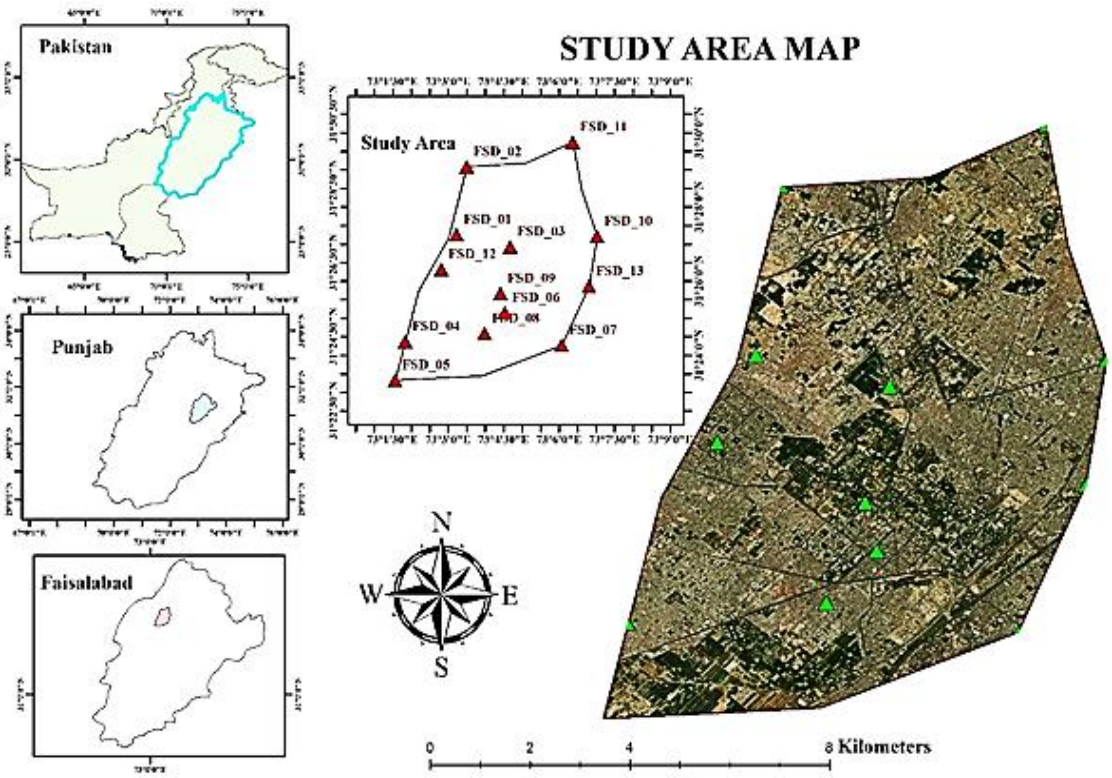


Figure 1. Description of the study area Faisalabad Pakistan

to determine EC, TDS, Turbidity, Nitrates, Arsenic and Fluorides. Geographical location of all sampling points was determined using GPS.

Table 1. Source and description of samples location

Sample_ID	Latitude (N)	Longitude (E)	Source of water
FSD_01	31.45428	73.05387	Borewell
FSD_02	31.48469	73.0584	Water pump
FSD_03	31.44867	73.07801	Borewell
FSD_04	31.40611	73.03069	Borewell
FSD_05	31.38881	73.02614	Water pump
FSD_06	31.41911	73.07565	Borewell
FSD_07	31.40442	73.10126	Water pump
FSD_08	31.40978	73.06657	Water pump
FSD_09	31.42776	73.07361	Water pump
FSD_10	31.45348	73.11727	Water pump
FSD_11	31.49573	73.10628	Borewell
FSD_12	31.43853	73.04695	Water pump
FSD_13	31.43097	73.1135	Borewell

***Water quality index (WQI)*:** The sampling locations were incorporated in arc map; these sampling points were exported to draw shapefile using polygon. The data EC, TDS, Nitrates and Florides were prepared using IDW method through interpolation (Aleem *et al.*, 2018).

Water Quality Index (WQI) is most efficient tool which could be used to draw water quality parameters on a scale on the basis of their influence on quality (Brown *et al.*, 1970). It utilizes to understand water quality aspects of complex data into a score value which is understandable by local community. It includes stepwise procedure like developing relative weights of influencing parameters (Wi), Water quality rating scale (Qi) which is ratio of concentration of parameters in the water sample to standard value of parameters defined by World Health organization (WHO), Pakistan Water Quality Standards (PWQS). Measuring of WQI is explained mathematically in equation below.

$$WQi = Wi \times Qi$$

Sum of all parameters provide a unique value which is compare with the values of table 2 to examine the water quality of particular sample.

Table 2. Category of water quality based on WQi (Aleem et al., 2018; Tyagi et al., 2013).

WQi	Water Rating
< 25	Excellent
25-50	Good
50-75	Poor
75-100	Very poor
>100	Unfit for consumption

Table 3 indicates the weight values of each parameter used in water quality index (WQI). These values are further used for the calculation of water quality index by using the equation mentioned above.

Table 3. parameters studied for WQI

Sr.	Parameters	Unit	PWQS	Weight assigned	Relative weight
1	EC	µs/cm	600	5	0.185
2	TDS	ppm	500	3	0.111
3	Turbidity	mg/l	0	4	0.148
4	Nitrates	ppm	10	5	0.185
5	Arsenic	ppm	10	5	0.185
6	Florides	ppm	1.5	5	0.185
				∑=27	**∑=1**

RESULTS AND DISCUSSIONS

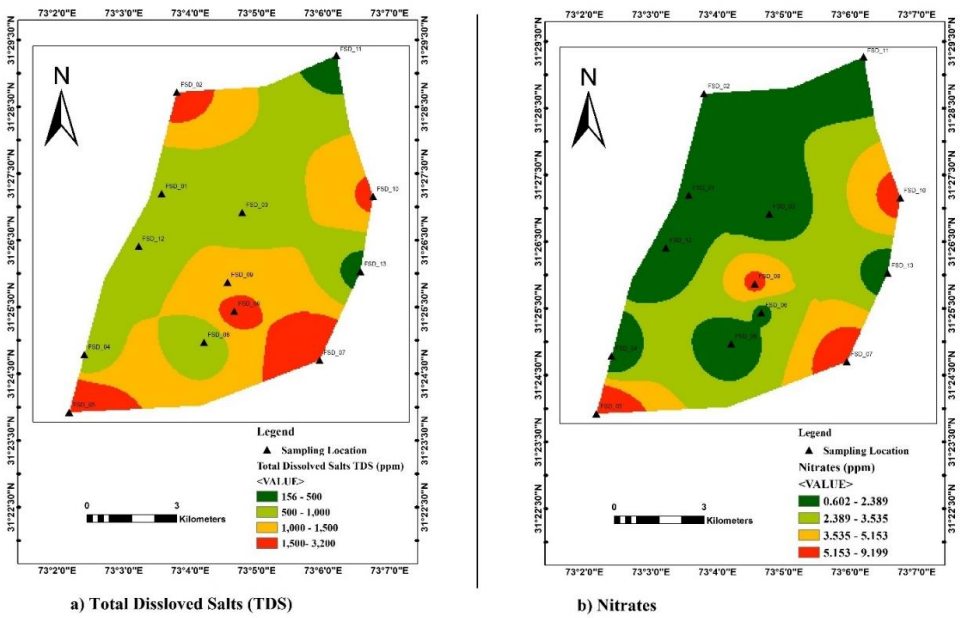
All the samples were pre investigate for the guideline values of NEQS. The results were shown in table 4, which also indicates that what percentage of samples were exceeding from the NEQS. No sample was found for turbidity which is exceeding the guideline values whereas, nitrate and arsenic concentration also found in samples. The exceeding percentage is mentioned in the table as "GV exceeding sample's %age".

Table 4. Overall percentage of samples which exceed guideline values

Sr.	Parameters	Unit	Guideline value (GV)	No. of parameters exceeding GV	GV exceeding sample's %age
1	EC	us/cm	600	10	77
2	TDS	ppm	500	9	69
3	Turbidity	mg/l	0	13	100
4	Nitrates	mg/l	10	2	15
5	Arsenic	mg/l	10	0	0
6	Fluorides	mg/l	1.5	1	8

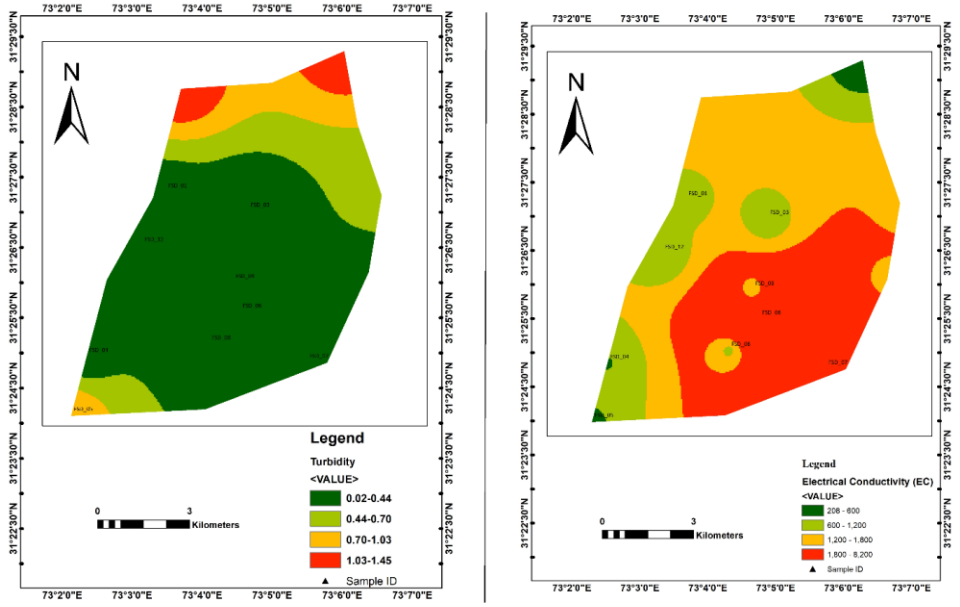
Total Dissolved Salts: Total dissolved salts are the sum of mineral salts (HCO3, Cl, Ca2+, K, Mg, Na and SO3) which present in water sample and these salts affect the water quality in taste and hygienity. However, its contamination has not reported serious illness, but its higher concentration is not permissible in water samples (Islam *et al.*, 2017). Various institutes have its permissible limits because on water quality like in Pakistan Water Quality Standards (PWQS) its limit is less than 500 while up to 1000 ml it is safe but greater than 1000 it is unsafe for human health. The GIS interpolation was shown in Fig. 2 for TDS and Nitrates.

Nitrates: Nitrates are found quit higher concentration in water samples due to mixing of fertilizer in soil profile and after leaching, it reaches to groundwater level and effect concentration with greater extent. Furthermore, it was observed in



a) Total Dissloved Salts (TDS) b) Nitrates

Figure 2. Total Dissolved Salts (TDS) and Nitrates variation map



a) Turbidity b) Electrical Conductivity (EC)

Figure 3. Turbidity and Electrical Conductivity map.

water samples variation of nitrates may cause blue baby syndrome in infinat. Maximum value observed in samples was 23 while in one sample no nitrates were found.

Turbidity: It denotes the clarity of liquids which is further defined as amount of light scattered by organic inorganic matter in water when light is shines through water samples. Maximum value of turbidity was observed as 1.45 while in safe limits it must be undetectable. The GIS interpolation was shown in Fig. 3 for turbidity and electrical conductivity (EC).

***Electrical Conductivity (EC)*:** EC refers to ability of water to pass current due to dissolved concentration of ions in water sample. Greater concentration of dissolved salts (ions) higher will be the EC value. It was observed that greater variation of

EC was observed in water samples. 8120 mg/l was observed as maximum value while 208 mg/l water minimum value of EC in water.

***Arsenic*:** Arsenic is one of dangerous elements which causes serious deceases to human beings, its permissible limit is below 10 mg/l. during analysis it was observed that no sample containing arsenic level beyond the permissible limit, however, maximum values was found 8.87 and minimum 0.12 mg/l. The GIS interpolation was shown in Fig. 3 for Arsenic and Fluoride.

***Fluorides*:** Fluorides are natural mineral decays which found in groundwater, it higher values may cause tooth decay to teeth. One sample was found with exceeding value and minimum value was determined as 0.1 mg/l.

***Statistical analysis*:** Descriptive statistical tool was use for the statistical analysis of all parameters and SPSS software was used for the analysis. Mean, maximum and minimum values were calculated for the above parameters. These values are also important for the groundwater investigation for the GIS tool utilization.

Table 5. Statistical analysis of samples.

Parameters	N	Mean	Max	Min
EC	13	1830.46	8120.00	208.00
TDS	13	1019.08	4466.00	114.00
Turbidity	13	0.53	1.45	0.02
Nitrates	13	5.55	23.00	0.00
Arsenic	13	3.83	8.87	0.12
Florides	13	0.57	1.49	0.1

Water Quality Index: Water quality index of thirteen samples was analyzed and its index rating was found between 22 and 375, detail is shown in Table 6. the resulted index map is shown in Fig. 5. which indicates that about 70% analyzed samples fall in poor water quality zone which 30% has good water quality index. The wide range 22 to 375 has individual aspects of EC, turbidity, TDS, nitrates, arsenic and florides concentration, major effect was found by variation of EC, TDS and arsenic concentrations. It is therefore concluded that water quality of Faisalabad tehsil is decreasing at alarming rate which resists direct consumption without treatment.

Table 6. Detail of Water Quality Index rating and Water quality aspect of analyzed samples .

Sr.	Sample_ID	Index rating	Water quality
1	FSD_01	54	Poor
2	FSD_02	96	Very Poor
3	FSD_03	51	Poor

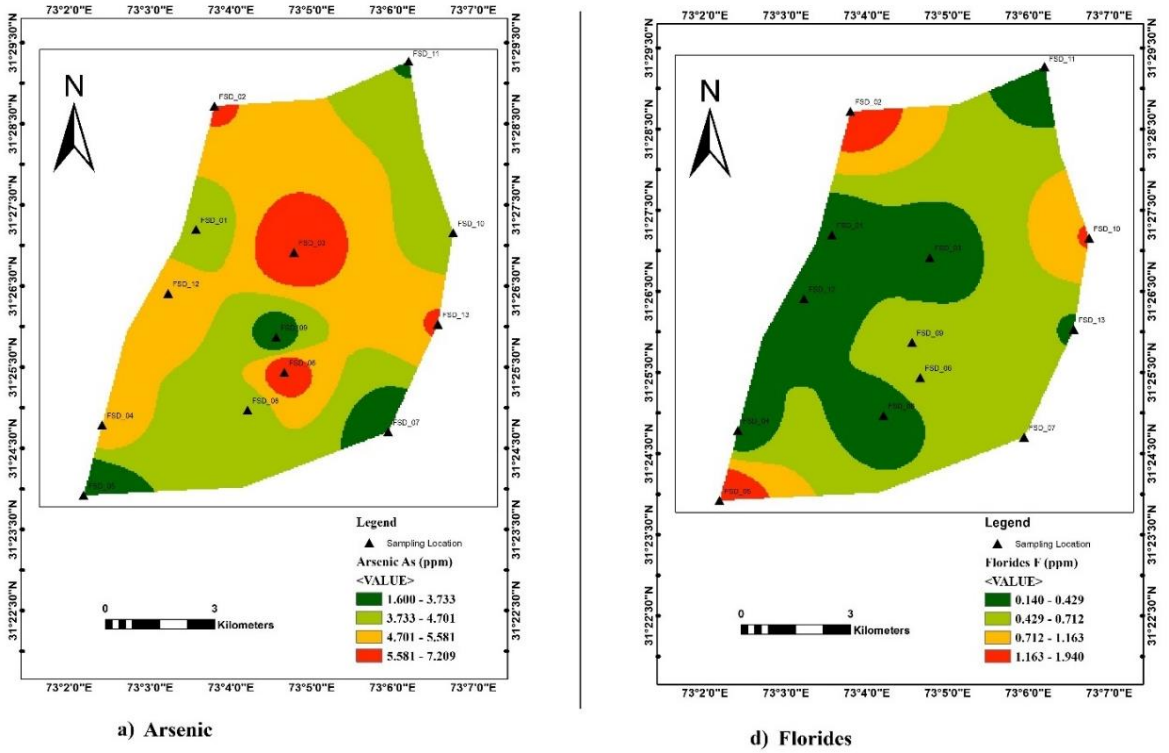


Figure 4. Arsenic and Florides map

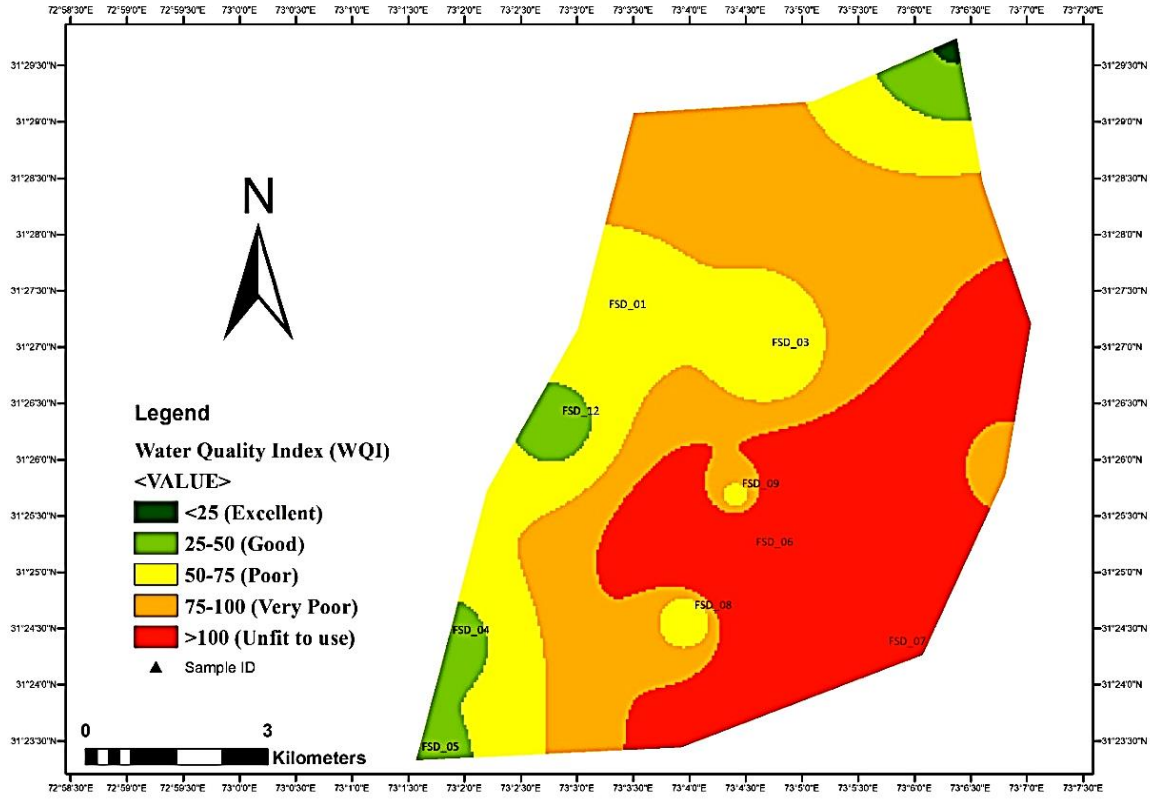


Figure 5. Water Quality Index map

4	FSD_04	41	Good
5	FSD_05	39	Good
6	FSD_06	375	Unfit
7	FSD_07	229	Unfit
8	FSD_08	55	Poor
9	FSD_09	65	Poor
10	FSD_10	105	Unfit
11	FSD_11	22	Excellent
12	FSD_12	37	Good
13	FSD_13	91	Very Poor

***Conclusion*:** All above discussion of parameters studied in Faisalabad city were found with unfit groundwater quality. The range of WQI was determined between 22 to 375. Overall water quality rating was found higher at most sampling location which indicated greater deterioration of water quality into poor to very poor and unfit for drinking purposes. It was concluded that the 7.5% samples contained excellent water quality, 23% contained good water quality while remaining 69% samples showed poor, very poor and unfit. This may lead to the human risks and alarming situation for the public health concern. The extensive consumption of poor water quality fading the human health and as well as agricultural sector. therefor it is necessary to improve the groundwater quality by using recharging techniques**.**

***Recommendation*:** After analysis it has been determined that overall water quality showed a deterioration trend and 69.4% sampling locations showed poor to unfit drinking water quality and it has great concern to government, policy making and public institutions. It was recommended that water should not be used for drinking without treatment. Water treatment plants should be installed for public usage in Faisalabad city to preserve health of living beings**.**

***Conflict of interest*:** Authors have no conflict of interest regarding to publish this manuscript.

***Authors Contributions statement*:** Muhammad Abbas and Muhammad Aleem collected data and perform the write-up. While Adil Altaf and Muhammad Waqar Akram contributed in GIS modelling and structuring of paper. and Noman Ali Butter, H. A. Raza assisted to review and improving the research article.

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